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FĀRESĪ, KAMĀL-AL-DĪN ABU'L-ḤASAN MOḤAMMAD

FĀRESĪ, KAMĀL-AL-DĪN ABU'L-ḤASAN MOḤAMMAD, b. Ḥasan (d. 721/1320), the most significant figure in optics after Ebn al-Hayṯam (Alhazen; 354-430/965-1040). The two names have been linked on account of Kamāl-al-Dīn's critical revision of Ebn al-Hayṯam's *Ketāb al-manāẓer,* which represents a watershed in the scientifi;c understanding of light and vision. Kamāl-al-Dīn's work, entitled *Tanqīḥ al-manāẓer le-ḏawī al-abṣār wa'l-baṣā'ir*, was for long assumed to be a commentary (*šarḥá*) on the *Ketāb al-manāẓer*. This impression was partly reinforced by the autobiographical information in the *Tanqīḥá*, which is the main source of what little we know about him.

Kamāl-al-Dīn relates (*Tanqīḥ*, ed. Hyderabad, I, pp. 4-9) having come to Tabrīz (possibly sometime before 1290) to study under Qoṭb-al-Dīn Šīrāzī (634-710/1236-1311), one of the distinguished team of astronomer-philosophers from the Marāḡa observatory in Azarbaijan. Kamāl-al-Dīn's concern with optics was already suffi;ciently established to question the statements of "leading philosophers" such as Naṣīr-al-Dīn Ṭūsī (Sabra, p. lxxi, n. 112), on the refraction of rays in water and on why stars appeared larger near the horizon than at higher altitudes. In response to Kamāl-al-Dīn's dissatisfaction with his readings, his teacher recollected having seen during his youth "a book on optics in two large volumes attributed to Ebn al-Hayṯam" in a library in Fārs and subsequently obtained a copy for Kamāl-al-Dīn "from a distant land." Fortuitous circumstances thus placed in Kamāl-al-Dīn's hands a unique work

which, in an extensive series of mathematical and experimental studies, had brought together for the fi;rst time the physics of light (dealing with rectilinear propagation, refl;ection, and refraction) and ocular anatomy to explain vision. Previous explanations based on visual rays, qualitative impressions, and indivisible forms were replaced by a new theory of an "optical" punctate image formed in the eye by light refl;ected from the surface of the object—a theory which marks the beginning of physiological optics (Russell, 1996). Qoṭb-al-Dīn Šīrāzī urged Kamāl-al-Dīn to write a commentary on Ebn al-Hayṯam as he himself was preparing one on the *Qānūn* of Avicenna (q.v.).

Kamāl-al-Dīn's work may have intended initially to prepare a "summary" (*eḵteṣār*) of the *Ketāb al-manāẓer* with a commentary (*šarhá*), as further indicated by the stylistic use of "he said" for paraphrases of Ebn al-Hayṯam's text and "I say" for his own statements. It clearly evolved into a critical revision (*tanqīhá*), not only of Ebn al-Hayṯam's work but also of the study of "optics" itself. First of all, the *Tanqīḥ* goes beyond the seven books of the *Ketāb al-manāẓer* to include in a sequel (*ḏayl*) and three appendices (*lawāḥeq*) recensions of other treatises by Ebn al-Hayṯam—on the halo and the rainbow (*Maqāla fī qaws qozaḥ wa'l-hāla*); the burning sphere (*al-Kora al-moḥreqa*), shadows (*Kayfīyat al-aẓlāl*), the shape of the eclipse (*Ṣūrat al-kosūf*), and a discourse on light (*Fi'l-żaw'*)—some of which were associated with astronomy and metereology. In so doing, Kamāl-al-Dīn redefi;ned the boundaries and provided a more comprehensive presentation of the science of optics (*manāẓer*). In the concluding section (*ḵātema*) of the *Tanqīhá*, he expanded Ebn al-Hayṯam's research on refraction in book 7 of the *Ketāb al-manāẓer* (Sabra, II, pp. lxii-lxiii). At the same time, utilizing the result of Ebn al-Hayṯam's investigations as well as experimental techniques in dark rooms or camera obscura (*al-bayt al-moẓlem*), he made innovative contributions in both physical and physiological optics which deviated from those of Ebn al-Hayṯam.

For example, a new explanation of the rainbow by Kamāl-al-Dīn accompanies Ebn al-Hayṯam's *Maqāla fī qaws qozaḥ wa'l-hāla* in the sequel to the *Tanqīḥ*. Radically departing from previous theories, it correctly accounts for the shape of the arc, the presence of the primary and secondary bows, and describes the order of colors in both, showing their reversal in the secondary bow. Kamāl-al-Dīn's explanation is distinguished by the originality of its experimental procedure where he substitutes a glass sphere fi;lled with water for an individual droplet, places it in a dark room with a single aperture, and investigates what happens as rays of light pass through his model. Inspired by

Avicenna's observation in the *Šefāʾ* that rainbows occur independently of the presence of dark clouds (traditionally assumed to serve as a concave mirror), Kamāl-al-Dīn ingeniously brings together in his experiment Avicenna's emphasis on water droplets and Ebn al-Hayṯam's studies of refraction in the *Ketāb al-manāẓer* and of parallel rays through transparent spheres in *al-Kora al-moḥreqa*. He correctly describes the lower primary bow as a result of two refractions (of rays entering and emerging from the waterdrop) with one internal refl;ection; and the secondary bow as a result of two internal refl;ections between the two refractions (for a detailed exposition, see Weidemann; Naẓīf; and esp. Rashed, 1973, pp. 213-18). His attempt to account for the colors, though unsuccessful, is of considerable interest in itself.

Kamāl-al-Dīn also extends Ebn al-Hayṯam's physiological optics by further studies of ocular anatomy and image formation as well as by providing additional diagrams (see Plate I and Plate II). He exploits Ebn al-Hayṯam's conception of the eye as an optical system, which was already a major departure from previous Greek and Arabic views (Russell, 1996), by using the excised eye of a ram as an experimental model in a dark room with a single aperture as a light source. In an attempt to correct Galen (Schramm, pp. 308-15), Kamāl-al-Dīn demonstrates that visible ocular images are formed by both refraction and refl;ection of light rays by the transparent parts of the eye. His accurate description and explanation of such images, one refl;ected from the cornea and a larger but fainter second one from the anterior surface of the crystalline lens, corresponds to two of the so-called Purkinje images which were described by Purkinje (1823) and Sanson (1837) in the 19th century (Russell, forthcoming).

Kamāl-al-Dīn takes optics signifi;cantly further than Eby al-Hayṯam in no longer relying on the mechanics of impact as an analogy to explain the behavior or light and image formation in the eye. His procedures introduce an important element into the scientifi;c study of natural phenomena—the testing of a theoretical conjecture or hypothesis by means of a model which corresponds to physical reality and which enables direct observation under controlled and repeatable experimental conditions (Rashed, 1973). In fact, some of the experimental techniques Kamāl-al-Dīn uses, and the understanding of scientifi;c procedures which he reveals, are usually associated with 17th century practices.

In contrast to the far-reaching infl;uence of Ebn al-Hayṯam's *Ketāb al-manāẓer* on the Latin West, Kamāl-al-Dīn remains its sole scientifi;c heir in optics in the

Islamic world with no progeny to date. There is no evidence that Kamāl-al-Dīn was ever translated into Latin, although comparisons have been made between his explanation of the rainbow and a similar one in Dietrich von Freiburg's *De iride et radialibus impressionibus* (ca. 1304-11). On the whole, the *Tanqīḥ* appears to have served to disseminate the content of the *Ketāb al-manāẓer* to fi;gures such as Taqī-al-Dīn b. Maʿrūf (d. 1585). Even after the discovery in this century of the original Arabic manuscripts of the *Ketāb al-manāẓer*, the *Tanqīḥ* still serves to fi;ll in what may be from the text and diagrams in its extant books (Sabra, II, p. lxxii).

The completion date of the *Tanqīḥ* has been controversial, placed from sometime before 1290 C.E. (Nazīf) to after 1302 C.E. but before Qoṭb-al-Dīn Šīrāzī's death in 710/1311 (Wiedemann; for a summary of the arguments and their implications, see Rashed, 1973, p. 218). The conclusions of the *Tanqīhá* are presented by Kamāl-al-Dīn in a separate work entitled *Ketāb al-baṣāʾer fī ʿelm al-manāẓer fi;'l-ḥekma*. He also has mathematical works, entitled *Asās al-qawāʿed fī oṣūl al-fawāʾed* (a commentary on the *Fawāʾed al-bahāʾīya* of ʿAbd-Allāh b. Moḥammad Ḵaddām [b. 643/1245]) and *Taḏkerat al-aḥbāb fī bayān al-taḥābb*.

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Plate I. The eye and optic nerves according to Kamāl-al-Dīn Fāresī in the Tanqīḥ al-manāẓer. Following Ebn Hayṯam, Kamāl-al-Dīn deviates from tradition and places the crystaline lens correctly in its forward position rather than in the center of the globe. The tunics and transparent humors of the eye are labeled as follows: sclera (ṣolba), cornea (qarnīya), aqueus humor (bayżīya), uvea (ʿenabīya), uveal aperture or pupil (ṯaqb ʿenabīya), region of the crown (mawżeʿ al-eḵlīl), arachnoid (ʿankabūtīya), crystalline humor (jalīdīya), and vitreous humor (zojājīya). In addition, Kamāl-al-Dīn includes the choroid tunic (mašīmīya) and retina (šabakīya) as well as the ocular muscles (ʿażalāt), which are not described by Ebn Hayṯam. After MS Istanbul, Topkapı Sarayı Kütüphanesi, Ahmet III 3340, f. 16a (dated 716/1316). Courtesy of G. Russell, from microfilm provided by Süleymaniye Kütüphaneler Müdürlüğü.

Plate II. The eye and optic nerves according to Kamāl-al-Dīn Fāresī in the Tanqīḥ al-manāẓer. The schematic diagram illustrates the eyeballs, optic foramen (ṯaqb), bony orbit (moqaʿʿar al-ʿaẓm), hollow optic nerve, two nerves coming together to form the optic chiasm (al-ʿaṣaba al-jawfāʾ al-moštareka), and the optic tract to the anterior part of the brain (moqaddam al-demāḡ). The parts of each eye, including the ocular muscles, are clearly labeled. The diagram represents a significant advance over that provided by Ebn Hayṯam in t he Ketāb al-manāẓer. After MS Istanbul, Sülemaniye Kütüphanesi, Fatih

3212, f. 81b. Courtesy of G. Russell, from microfilm provided by the Süleymaniye Kütüphaneler Müdürlüğü.